Dynamic Pricing for E-Commerce

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INTRODUCTION

Over the last decade, e-commerce has significantly changed the traditional forms of interaction among humans in conducting business by automating business processes over the Internet. Early seller Web sites consisted of passive text-based catalogs of products that could be manually browsed by potential customers. Online passive catalogs were soon replaced by dynamically updated catalogs containing detailed product descriptions using combinations of text and images that could be searched in various formats and according to different search criteria. E-commerce techniques used by sellers for operations such as price setting, negotiation, and payment have matured from manual off-line processing of sales data to automated algorithms that dynamically determine prices and profits for sellers. Modern e-commerce processes for trading goods between buyers and sellers can be divided into five stages: search, valuation, negotiation, payment, and delivery. Depending on the type of market in which the goods are traded, some of the above stages are more important than others.

There are three principal market models that are used for online trading. The most common market model used by online sellers for trading goods over the Internet is the posted-price market model. The other two market models, the auction model (Sandholm, Suri, Gilpin, & Levine, 2002) and the marketplace model (Chavez & Maes, 1996), are used for markets in which niche or specialty items with sporadic or uncertain demand are traded.

In the posted-price market model, a seller announces the price of a product on its Web site. Buyers visiting the seller's Web site request a quote from the seller. The seller responds with a quote in response to the buyers' requests, and the buyers examine the seller's quote to make a purchase decision. Unlike auctions and marketplaces, products traded in posted-price markets are no-niche items and exhibit continuous demand over time. The Web site of online book merchant Amazon (http://www.amazon.com) is an example of a posted-price market. A buyer interested in a particular book enters the necessary information through a form on Amazon's Web site to request the price of the book and receives the price in response.

Modern seller Web sites employ automated techniques for the different stages of e-commerce. Intermediaries called *intelligent agents* are used to automate trading processes by implementing different algorithms for selling products. For example, Web sites such as MySimon (http://www.mysimon.com) and PriceGrabber (http://www.pricegrabber.com) automate the search stage by employing the services of intelligent agents called *shopbots*. Shopbots enable buyers to make an informed purchase decision by comparing the prices and other attributes of products from thousands of online sellers. Automated price comparison by buyers has resulted in increased competition among sellers. Sellers have responded to this challenge by using intelligent agents called *pricebots* that dynamically determine the price of a product in response to varying market conditions and buyers' preferences. Intelligent agents are also used to enable other e-commerce processes, such as supply-chain management and automated negotiation.

In this article, we focus on the different algorithms that sellers' pricebots can use for the dynamic pricing of goods in posted-price markets.

BACKGROUND

Over the past few years, online dynamic pricing has stimulated considerable interest in both the commercial and research communities. Increased profits and rapidly clearing inventories resulting from efficient pricing have encouraged the development of software pricing tools including Azerity (http://www.azerity.com) and Live Exchange (http://www.moai.com). Automated dynamic pricing for posted-price markets has been implemented and analyzed using simulated market models (Brooks, Gazzale, MacKie-Mason, & Durfee, 2003; Dasgupta & Melliar-

Smith, 2003; Kephart, Hanson, & Greenwald, 2000). Most of these models consider the price of a product as the only attribute affecting a buyer's purchase decision. Surveys of consumers who purchase products online, reported in Brown and Goolsbee (2000) and by ResellerRatings (http://www.resellerratings.com), reveal that online buyers are frequently willing to pay an elevated price for particular product attributes such as delivery time, seller reputation, and service. Moreover, the preferences of buyers vary over time depending on exogenous factors such as sales promotions, aggressive advertising, and the time of year. Therefore, it is important for an online seller to differentiate a product using multiple attributes and to determine the purchase preferences of a potential buyer over those attributes so that the seller can tailor its offer to the buyer's requirements and improve its profits.

In online markets, a seller must determine the prices that its competitors charge for a product so that it can place its price at a competitive advantage. The rapid fluctuation of market prices can leave a seller with outdated competitor price information that can cause the seller's dynamic-pricing algorithm to function incorrectly. However, it is difficult for sellers to obtain prior information about buyers' parameters. Therefore, it is desirable if online sellers do not assume prior knowledge about market parameters, but rather use a learning algorithm (Brooks et al., 2003; Dasgupta & Hashimoto, 2004) to determine changing market parameters dynamically.

DYNAMIC PRICING USING INTELLIGENT AGENTS

In an automated posted-price market, a seller employs the services of a pricebot that dynamically calculates a profit-maximizing price of a product in response to fluctuations in market parameters, such as the prices and profits of competing sellers and the reservation prices of buyers. The seller posts the updated product price at regular intervals to attract buyers while maintaining a competitive edge.

The market model we consider is based on the shopbot economy model of Kephart, Hanson, and Greenwald (2000), which makes simplifying assumptions about the online economy that facilitate analysis while retaining the essential features of the market. It consists of *S* sellers who compete with each other for *B* buyers ($B \gg S$). Only one type of commodity is traded in the market. A seller behaves as a profit maximizer and has a sufficient supply of the commodity for the lifetimes of the buyers. Buyers return to the market repeatedly to purchase the commodity. Examples of such markets include telephone and Internet services.

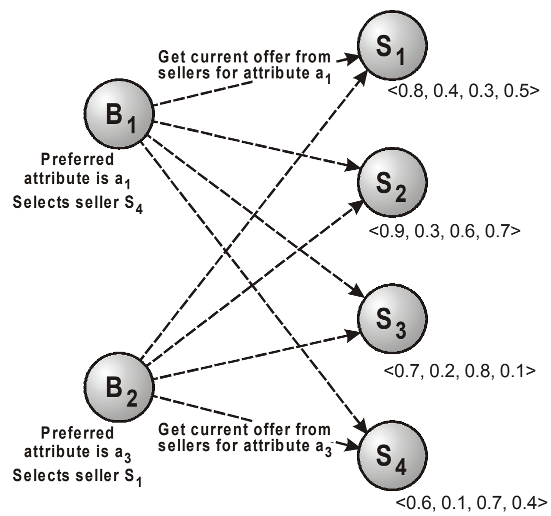
A product is characterized by multiple attributes. A seller offers a slightly different price for the product along each of its attributes. As shown in Figure 1, a buyer first requests a quote from the sellers for the price based on his or her preferred product attribute, and then selects the seller that makes the best offer. The buyer's preferred attribute is not revealed to a seller when the buyer makes a quote request. Therefore, a profit-maximizing seller must determine a buyer's preferred attribute in response to the buyer's quote request. The seller then calculates a competitive price for the product along the buyer's preferred attribute and makes an offer to the buyer.

Dynamic-Pricing Algorithms

Because online sellers are profit maximizers, the objective of a seller is to determine a price for each attribute of the product that maximizes the seller's profit. However, the pricing function of a seller cannot be stationary as there are other competing sellers who revise their prices to improve their offers and attract buyers away from each other. Therefore, the seller updates the prices it charges on different product attributes at intervals in response to competitors' pricing strategies and changes in the buyers' preferred attributes.

We describe in the following sections some pricing algorithms used by an online seller's pricebot to determine the price of a product. We omit the subscript for

Figure 1. A hypothetical market showing two buyers, B_1 and B_2, with preferred attributes a_1 and a_3, respectively, making a quote request to four sellers, S_1, S_2, S_3, and S_4, and then selecting the seller that offers the best price for the product on their respective attributes. The four-tuple below each seller denotes the normalized price on the different product attributes offered by that seller.



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